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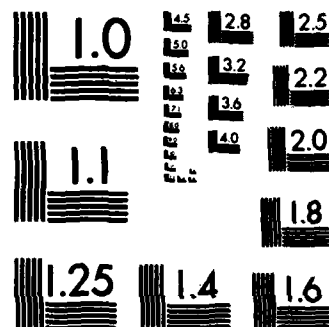
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# ONR LONDON CONFERENCE REPORT

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## OFFICE OF NAVAL RESEARCH

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ENGLAND

THE EUROPEAN UNDERSEA BIOMEDICAL SOCIETY  
ANNUAL CONVENTION

CDR A.R. MANALAYSAY, USN

July 18, 1983

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) ✓ The conference dealt with topics ranging from basic physiology to clinical case presentations. In addition to the scientific sessions, the conference included visits to GUSI, the new hyperbaric facility that Dragerwerk AG is building; the West German submarine escape training facility in Neustadt; and the hyperbaric works at Dragerwerk AG in Lubek.		

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## THE EUROPEAN UNDERSEA BIOMEDICAL SOCIETY ANNUAL CONVENTION

The European Undersea Biomedical Society (EUBS) held its eighth annual convention from 5 through 9 October 1982 in Lubeck-Travemunde, West Germany. The official program included presentations on a variety of issues relevant to the undersea environment. Topics ranged from basic physiology to clinical case presentations. In addition to the scientific sessions, the organizers arranged for delegates to visit three facilities: GUSI, the new hyperbaric facility that Dragerwerk AG is building in Geesthacht for the West German government; the West German submarine escape training facility in Neustadt; and the hyperbaric works at Dragerwerk AG in Lubeck. While many within the EUBS organization were responsible for the success of the convention, three people in particular deserve mention: Dr. David Elliott, Dr. T.G. Shields, and Captain K. Seeman.

### Reports From Scientists on the Staff of Dragerwerk AG

Dragerwerk AG is a multidisciplinary West German company. One of the firm's areas expertise is fabricating and installing hyperbaric facilities. Since the firm does a good deal of development work in hyperbaric systems, its scientists were invited to speak about various diving-related research projects.

Dr. W. Lubitzsch gave a general review of the contributions made to the diving industry by Dragerwerk AG and by German scientists in general. Lubitzsch's discussion also indicated that the current research programs are broad based and comprehensive, ranging from basic physiology to ergonomic studies.

Dr. P. Wiesner described a system for automatically monitoring and controlling hyperbaric chamber atmospheres. The system was designed specifically for GUSI but can be adapted to any other facility. Gas analyses are carried out automatically, and the chamber gas is modified automatically. These functions

are controlled by a computer linkup, with full redundancy built in; appropriate emergency measures and sub-routines also are built in. The operator can manually override any function at any time, and complete documentation of all that goes on can be made available in hard copy.

Lubitzsch made another presentation on behalf of Dr. J. Gelhaus. The paper described a helium reclamation facility. Helium is the most common inert gas used for deep saturation diving. Reclaiming the used helium is a prime consideration because the gas is expensive. Gelhaus' work relies on the principle of molecular sieving to remove and purify the spent helium. In the basic configuration, the helium reclamation facility can handle 25 m<sup>3</sup>/hr and can deliver a helium purity of 80 to 95%. A typical output gas analysis shows the following: O<sub>2</sub><0.5%, CO<sub>2</sub><10 VPM, N<sub>2</sub><0.4%, CO<2 VPM, and hydrocarbons and CH<sub>3</sub><1 VPM.

Dr. K.H. Hartung described recent work being carried out by Dragerwerk AG in the field of oxygen-enriched breathing gases. The study is based on the concept of "equivalent air depth" diving. The idea is that the use of higher oxygen concentrations (higher than is normal for air) invariably results in lower inert gas concentrations in the breathing gas. This then leads to less nitrogen exposure for the diver using the modified breathing gas. The result is that the diver absorbs less nitrogen. Thus, less time is needed for decompression than if the diver were breathing air. The problem of oxygen toxicity at high concentrations limits the degree to which this type of manipulation can be applied safely. The trick is to maximize the benefit of higher oxygen concentrations while minimizing the toxicity inherent in high oxygen mixtures.

### Diving Regulations

Dr. D.H. Elliott discussed the European Diving Technology Committee's (EDTC) recent revision of the "Guidance Notes for Safe Diving." The EDTC, made



up of representatives of the European Economic Community, now cannot enforce its recommendations. The committee's primary aim in drafting the notes was to improve the health and safety of the diving population--specifically in industrial or commercial diving. The text of EDTC's recommendations is outlined below.

#### *Medical Requirements in Support of Diving Operations*

A. Medical Support of Diving Operations. Each member country is expected to ensure that appropriate mechanisms are established such that the following can be accomplished.

1. Set criteria for assuring that the diver is properly examined and the needed tests are carried out to allow one to conclude that the diver is medically fit. Set criteria for declaring a diver unfit either because of illness (including decompression sickness) or injury. This also implies setting criteria for restoring a diver's medical fitness for diving following illness or injury.

2. Render advice to employers on methods and procedures which would help to achieve the above indicated aims.

3. Attend to the diver in the acute phase of injury as well as in the later rehabilitative phase.

4. Train diving personnel in first aid procedures. The training is to be tailored to the isolated environment in which personnel will be working and should include appropriate emphasis on the medical problems unique to diving.

5. Conduct and support biomedical research into occupational health, physiological, and clinical aspects of diving.

B. In order to accomplish the aims set out in section A, each member nation shall, at the minimum, perform the following.

1. Provide for adequate training of doctors.

2. Establish medical standards.

3. Establish and provide guidance to regional diving medical centers.

4. Coordinate medical research and maintain a central registry for data related to diving accidents and medical examinations of divers.

#### *Medical Services, Definitions*

A. Doctors. The use of the term "Diving Doctor" is to be discouraged as it is ambiguous; the use of the term "physician" is likewise discouraged as other countries use the term to denote a non-medical scientist.

1. The "examining doctor."

- a. Should be trained to perform adequate medical examinations to ascertain fitness for diving.

- b. Does not have to be qualified for pressure exposure.

- c. Should have a minimum of 30 hours of approved instruction.

- d. Should maintain continuing medical education in the field.

2. The "emergency care doctor."

- a. Must be capable of undergoing pressure exposure.

- b. Should have a minimum of 60 hours of training in both theoretical and practical aspects of diving medicine.

- c. Preferably would have actual underwater experience as opposed to dry chamber experience only.

- d. Should maintain continuous medical education in the field.

3. The "specialist in diving medicine."

- a. Should be of consultant standing, one whose experience allows him/her to render advice to doctors in the prior two classifications.

- b. Should be a doctor with an expert knowledge of diving physiology.

- c. May be a specialist in some other branch of medicine (e.g., ENT) not related to diving, who nevertheless has consultant standing in his/her own special branch of medicine which is pertinent to diving.

- B. Medical Attendants.

1. Have no direct diving requirements.

2. Do not have to be pressure qualified.

3. Should be cognizant of diving-related disorders.

C. Divers.

1. All divers should have basic first aid, and, preferably, cardiopulmonary resuscitation instruction.

2. At least one member of the saturation team should have training as a paramedic or emergency medical technician, and must be ready to perform routine nursing care, including;

a. Parenteral administration of medications.

b. Insertion of urethral catheters.

c. Gastric intubation.

d. Thoracentesis.

e. Placement and management of an esophageal obturator airway.

D. Diving Contractors. All diving contractors must arrange appropriate medical cover for every dive. This may be accomplished via the regional diving medical center.

*Medical Examination of Divers*

Details on the standards for medical fitness of divers are contained in the pamphlet from the Health and Safety Executive, and also in the Royal Navy DCI 627/81.

*Research*

Research will be carried out in order to assure that the long term effects of diving are adequately understood. This also implies that an appropriate data base on diving medicine and accidents exists.

Diving Accident Reports

Dr. E. Lorenzoni from the Neurology Department of the Hannover Medical School reported on a series of 39 diving accident cases. Of the 39, six were fatal, 21 resulted in permanent damage, and 11 progressed to full symptomatic recovery. When the available evidence was reviewed, seven cases were felt to be due to diver inexperience, leading to incorrectly calculated decompression times; seven other cases were associated with emergency training. In six cases,

poor physical and mental conditioning was believed to be the main cause of the accident. Of the 39 cases, the causes of only nine were unknown.

Dr. P. Laverick (Bass Strait Services, Victoria, Australia) reported on two cases of severe, high-spinal-cord decompression sickness. Both cases were associated with inadequate decompression times; recompression was delayed by 2 hours in one instance, and by more than 7 hours in the other. In both cases, in-water decompression was attempted after surfacing. One case was managed with oxygen therapy at 60 feet; the other case was taken to 300 feet on heliox for 102 hours, followed by saturation decompression. Subsequent discussion centered around the desirability of taking such cases to depths greater than 60 feet if rapid resolution of symptoms does not occur at 60 feet on oxygen. There are advocates on both sides; unfortunately, the medical community has insufficient experience to make definite recommendations. A question such as this is best resolved by a multi-center approach carried out over enough time to allow cases to accumulate. Or if there were an adequate animal model for spinal cord decompression sickness, statistically valid random assignment of one of two therapeutic modes could be carried out.

Dr. E. Vroege (Erasmus Univ., Rotterdam, Holland) discussed the effect of circadian rhythms on a person's susceptibility to decompression sickness. In Vroege's study, caisson workers were assigned to groups based on the time of day that they were at work under pressure. The cases of decompression sickness were then examined with respect to time of day of onset. Vroege's results showed that most cases of decompression sickness occurred between 1 a.m. and 4 a.m., and in workers who had been on a shift ending around 11 p.m. In the discussion that followed, members of the audience indicated that the UK and French literature agreed with the Dutch study. In fact, it appears that the French already

anticipate such problems by using slightly higher oxygen tensions during the night shifts.

#### Diving Physiology

Dr. Z. Torok (Admiralty Marine Technical Establishment Physiology Laboratory, Alverstoke, England) presented a proposed classification scheme for the many signs and symptoms associated with the high pressure nervous syndrome (HPNS). The proposed scheme divides the symptoms into three groups: cerebellar, vestibular, and autonomic. Each group of symptoms has an independent course of progression. The cerebellar symptoms are characterized by ataxia and intention tremor. The vestibular symptoms include nausea, emesis, and visual and equilibrium disturbances. The autonomic symptoms include diaphoresis, clammy skin, epigastric symptoms, anorexia, and gastrointestinal disorders. The proposed classification scheme is acknowledged to be descriptive, illustrating rather than defining etiologic mechanisms.

Dr. M. Garrard (Admiralty Marine Technical Establishment Physiology Laboratory, Alverstoke, England) described his work on endocrine changes during decompression from deep dives. Garrard showed evidence for previously unnoticed and unexpected increases in circulating insulin, glucagon, and aldosterone during decompression from deep saturation dives. The implication was that the alpha and beta cells of the pancreas, and the juxtaglomerular cells of the kidney might be affected by decompression procedures in an otherwise asymptomatic individual. If so, this could represent a subclinical decompression sickness. The hormonal changes described cannot be explained and appear to be anomalous rather than reactive.

Dr. A.G. Macdonald read a paper for Dr. M.L.J. Ashford (Physiology Department, Marischal College, Univ. of Aberdeen) on the effect of hydrostatic pressure and octanol on the conductance change produced by acetylcholine at the frog neuromuscular junction. The aim of

the study was to shed light on the mechanism whereby pressure and anesthetics affect nerve conduction. The idea has been advanced that anesthetics (and by extension inert gases in narcotic concentrations) decrease membrane microviscosity, whereas pressure increases it. This hypothesis has been cited in certain quarters as an explanation for the observed pressure reversal of anesthesia. The Aberdeen group chose to examine the effect of pressure and anesthesia on the miniature end plate current (MEPC) of a synapse.

As an action potential impulse reaches the presynaptic membrane, acetylcholine in vesicles is released and stimulates the post-synaptic membrane. By positioning a microelectrode against the postsynaptic membrane, one can measure the MEPC. In this manner, one can observe and record the waveforms and note the effects induced by either pressure or anesthesia. In this model, the time course of the MEPC is believed to reflect the underlying conductance of the membrane. The Aberdeen group showed that low concentrations of octanol (50 to 100  $\mu\text{M}$ ) will decrease the time constant of decay ( $T_d$ ) of the MEPC. If the system is then exposed to pressure (up to 50 ATA), the  $T_d$  is further decreased; i.e., the effect is additive and not antagonistic. If the model is exposed to pressure alone below 75 ATA, there is little effect, if any, on the MEPC. The results suggest that pressure and anesthetics have different mechanisms of action on nerve conduction.

Dr. H. Padbury (Admiralty Marine Technical Establishment Physiology Laboratory, Alverstoke, England) reported on her studies of immersion hypothermia. Padbury used human volunteers and subjected them either to rapid cooling over a short time, or to slow cooling over a long time. The subjects were instrumented to allow rectal temperature measurement, and heat flow sensors were affixed to various parts of the body to allow an estimate of net heat flow. The main aim of the study



was to correlate changes in rectal temperature with net heat loss. The results show that slow cooling resulted in less heat loss per degree drop in rectal temperature than did rapid cooling. In this study, rapid cooling was performed by immersing the nude subject in water of  $<15^{\circ}\text{C}$  for 40 to 60 minutes. Slow cooling involved immersing the nude subject in water that was progressively cooled from 32 to  $28^{\circ}\text{C}$  over 4 hours.

Dr. I.H. Thomas (Royal Victoria Infirmary, Newcastle upon Tyne, England) described a study of how bone and marrow blood flow in miniature swine is affected by exposure to compressed air. Bone and marrow blood flow was measured in unanesthetized miniature swine using a radiolabeled microsphere method. The results indicate that exposure to compressed air (i.e., higher-than-normal oxygen tensions) resulted in larger fat cells and decreased blood flow in the femoral head and midshaft of the femur. It is believed that the increase in the size of fat cells may be related to diminished function of the sodium pump in the cell membrane leading to increases in cell hydration. Another finding was that the fatty bone marrow was very poorly perfused; thus, the saturation half time for this tissue for nitrogen may be very long.

Dr. H.O.E. Rockert (Histology Department, Univ. of Gothenburg, Sweden) discussed a study of the permeability of cartilage in rats of various ages to nitrogen, oxygen, and helium *in vitro*. The results show that increasing age is associated with increasing cartilage density and decreasing permeability to nitrogen, oxygen, and helium. It should be noted that various studies indicate increasing age is associated with increased joint-related decompression sickness symptoms.

Dr. F. Lind (Department of Environmental Medicine, Karolinska Institute, Stockholm, Sweden) reported on exercise tolerance studies in hyperbaric air. The main purpose of the study was to determine the highest work rate and exercise ventilation that a subject

could maintain for at least 6 minutes at various pressures. Seven normal male subjects were exposed to air in a chamber at 1, 4, and 6 ATA. At each pressure, the subjects performed ventilatory tests and incremental load exercise tests. The latter tests were done on a bicycle ergometer, with the work rate being increased from 150 W in 40-W steps every 6 minutes until the point of exhaustion. Maximal work level ( $W_{\text{max}}$ ) was the same in all subjects at 1 ATA (270 W), but was higher (310 W) in two subjects at 4 ATA and 6 ATA, and lower (230 W) in one subject at 6 ATA. The results suggest that there are no ventilation-imposed exercise limitations in most subjects at elevated air pressures up to and including 6 ATA--if the external breathing resistance is negligible.

#### Hyperbaric Oxygen Therapy

Dr. G. Frey (German Federal Armed Forces Hospital, Ulm, West Germany) presented two cases involving the use of hyperbaric oxygen in treating gas gangrene in the pelvis of females. In each case, the infection was a complication of an illegal abortion. One case required extensive amputation, whereas extensive fasciotomy was used in the other. Frey emphasized that in such anaerobic infections proper management should include surgical procedures as necessary, appropriate antibiotics, and hyperbaric oxygen therapy. Neglecting one of the three may lead to less-than-adequate outcomes.

#### New Hyperbaric Facilities

Two hyperbaric facilities are being completed in West Germany. The facilities have some overlapping capabilities but are not in competition with each other; rather, they are intended to be complementary. The newer is GUSI; the other is TITAN, which is in Köln.

Dr. J. Holm (Dragerwerk AG) described the GUSI facility. A complete diving simulation facility, GUSI is designed primarily for evaluation of both hardware and technical procedures under realistic in-water diving condi-

tions. Investigations at GUSI can be carried out in the manned mode down to 600-m depths, and in the unmanned mode to 1,000-m depths. The designers have maximized the use of automated procedures controlled by computers with extensive backup routines. Holm also pointed out that with such a system there are no set standards for certification; and in this particular case, extensive collaboration and cooperation between industry and government were responsible for the eventual certification of the facility. Holm said that GUSI should be functional to at least 350 m by the spring of 1983.

Dr. N. Luks (Institute for Aviation and Underwater Medicine, Köln) said that TITAN, which should be fully operational by mid-1983, is primarily intended for biomedical investigations. The system consists of four chambers, including a 12-m wet pot, which can be operated either individually or in various combinations. The complex can carry out manned saturation dives to 1,000 m; the unmanned capability is 1,500 m. The initial research plans at TITAN include evaluation of dive profiles and decompression schedules. The facility will also be used in the selection and training of divers.

#### New Techniques

Dr. R. Kaiser from the TITAN facility reported that the system has been used to evaluate decompression tables. Nitrogen elimination during decompression was measured by a technique based on the principle of laser magnetic resonance (LMR). The method is extremely sensitive and is promising. The study also involved the use of increased  $O_2$  concentrations in the breathing gas to help minimize the decompression time for bounce dives in the region of 200 m; a transcutaneous oxygen monitor was used with the LMR  $N_2$  monitor to follow the decompression process. The investigators at TITAN also intend to perform a series of saturation dives to 500 or 600 m, during which they plan to study aspects of the HPNS and pulmonary function changes.

Dr. J.M. Davies (Department of Physical Chemistry, South Parks Road, Oxford, UK) described an integrating ultrasonic imaging system used to detect intravascular and extravascular bubbles in man. The system does not involve Doppler effects but is an ultrasonic pulse-echo imaging system. A 64-element, 5-MHz linear array transducer is used to generate cross-sectional video images through tissue. The number of echoes forming each image frame is displayed. Bubbles formed within the scan plane increase the echo count. In a series of 48 manned dives conducted in the chambers of the Admiralty Marine Technical Establishment Physiology Laboratory in Alverstoke, the tissue areas scanned were the knee and the thigh. Three decompression-related incidents requiring treatment were observed. Extravascular gas phase formation during both symptomatic and asymptomatic dives was also observed.

Dr. R. Guillerm (DCAN TOULON, Toulon, France) reported on a Doppler method of bubble detection in minipigs. Guillerm used a chronically implanted detector and a modular detection set combined with a data-collecting and signal-processing unit. The method permits real-time plotting of the bubble flow profile during simulated air dives. The system and the minipig model are being used to evaluate various decompression schedules.

#### Deep Ex II

Deep Ex II is the second in a series of simulated deep dives carried out at the Norwegian Underwater Technology Center (NUTEC). Dr. S. Tonjum described the overall program; other investigators from NUTEC reported on the different aspects of the dive. Deep Ex II was completed on 30 November 1981, and was aimed at extending working dive capabilities to 500-m depths. The 34-day operation was ambitious and highly complex. It included 15 research projects involving physiological and performance studies in the dry chamber, as well as underwater investigations. The various areas of study during the dive included investigations of tungsten

inert gas and electrode welding techniques, environmental monitoring, and hypothermic immersion studies.

Two sets of three divers were compressed in parallel but different systems; one set of three divers underwent rapid heliox compression; the other set of divers underwent a slow trimix (10% N<sub>2</sub>) compression. After a period of time at depth, the divers compressed on trimix were switched to heliox.

Several records were established, including the deepest lockout (504 m), the longest continuous in-water exposure at extreme depth (182 minutes at 504 m), and the deepest manned welding (500 m). In-water performance studies showed that divers can adequately perform tasks normally expected of them at pressures up to 500 m. The execution time for the tasks may be increased because of the impaired fine motor control and the reduction in physical endurance; the quality of the work, however, was comparable to that performed at shallower depths.

Dr. A.O. Brubakk described a system for obtaining ultrasonic Doppler data in a hyperbaric chamber. The system is based on a pulsed Doppler velocity meter. The instrument can be operated in both the continuous and pulsed mode and uses the ultrasonic frequencies of 1, 2, 5, and 10 MHz. Signal-to-noise ratio is optimized by locating the preamplifiers inside the chambers. A communication system enables the diver and the operator to listen to the doppler signals. A cassette tape recorder modified for the 40-kHz bandwidth is used with a modulating-demodulating system, making it possible to record Doppler signals, two auxiliary signals, and spoken commentary. The system has been used in manned dives and has performed satisfactorily.

Dr. R. Vaernes reported on an evaluation of compression techniques for deep diving, with specific emphasis on HPNS and related problems. Two groups of divers were compressed to 500 m using heliox and trimix as described above. The compression employing trimix was

identical to the slowest profile used by the Duke Univ. Hyperbaric Research group in their ATLANTIS III dive. Neuropsychological and neurological tests were conducted throughout the compression periods. Both groups of divers suffered from HPNS, with one man significantly affected and one moderately affected in each group. Two subjects in the heliox group had a marked increase in tremor; this was not noted in the trimix group. However, the trimix divers had impaired motor and cognitive performance indicative of nitrogen narcosis. The heliox divers did not exhibit inert gas narcosis.

The divers were tested again after a period of stabilization at 500 m. The heliox group had a sustained and pronounced tremor during the period; on the third day at 500 m, the heliox group tested up to pre-dive levels on visuo-motor and cognitive tests. However, the trimix group's visuomotor and cognitive functions remained severely impaired throughout the period of time at 500 m on trimix. After the fourth day at 500 m, the divers in the trimix group were switched to heliox. There were minor changes in the EEG during the gas change; however, there was a marked increase in tremor and an improvement in cognitive function. Six hours after the gas change was completed, severe symptoms occurred, including visual hallucinations and myoclonic jerks; these symptoms resolved over a 12-hour period.

Electroencephalographic changes typical of HPNS were similar for both groups. Vaernes concluded that trimix did not inhibit HPNS during compression to 500 m. Trimix did have the disadvantage of causing inert gas narcosis and an increase in breathing gas density. Vaernes further concluded that heliox appears to be the preferred medium for dives to 500 m.

Dr. J. Paciorek described erythrocyte morphological changes in the Deep Ex II subjects. The self-manipulation of the erythrocyte through the general circulation depends on a highly specialized cytoplasmic surface membrane network, the cytoskeleton. In

Paciorek's study, the erythrocytes were fixed at pressure in 8% glutaraldehyde before decompression. Scanning electron microscopy showed a significant increase in distortion of the cells. The numbers of abnormal cells increased with pressure exposure and fell during the last 10 days of decompression. Paciorek also presented data indicating that the erythrocyte membrane cholesterol content increased during pressure exposure.

Dr. A. Pasche investigated the ventilatory  $\text{CO}_2$  response following deep saturation dives. The six divers in Deep Ex II underwent a ventilatory  $\text{CO}_2$  response test in the pre-dive phase using a rebreathing technique. The divers repeated the test immediately after the dive; blood samples were taken and analyzed for pH,  $\text{pCO}_2$ ,  $\text{pO}_2$ , and  $\text{HCO}_3^-$ . The results indicated that the divers had an increased sensitivity to  $\text{CO}_2$  after the dive. The findings agree with similar research at NUTEC in Deep Ex I, but contradict an earlier study in which saturation divers living in pressurized environments for 3 to 4 weeks exhibited a decreased ventilatory response to  $\text{CO}_2$ . All subjects ex-

hibited abnormal acid base balance within the first 24 hours decompression. Each subject showed a decrement in erythrocyte carbonic anhydrase activity.

Pasche also conducted a project on diver heating during simulated lockout dives at 500 m. The six divers performed standardized work during simulated lockout dives in water of 4 to 6°C at 500 m. The divers used conventional hot water suits, thinsulate underwear, and a newly developed breathing gas heater. The divers performed 17 dives, with an average dive duration of 86 minutes. The longest dive was 182 minutes. The results confirmed earlier observations that divers are very sensitive to breathing gas temperatures at high pressures. At 500 m, breathing gas temperatures between 30 and 32°C were considered comfortable. Breathing gas at 28°C was considered cold, while temperatures above 33.5°C were uncomfortably high. The divers' mean skin temperature and the temperature of the hot water supply to the suit varied considerably from dive to dive, even though the hot water flow settings were unchanged. The experiments confirmed the known narrow comfortable temperature zone at high pressures.

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